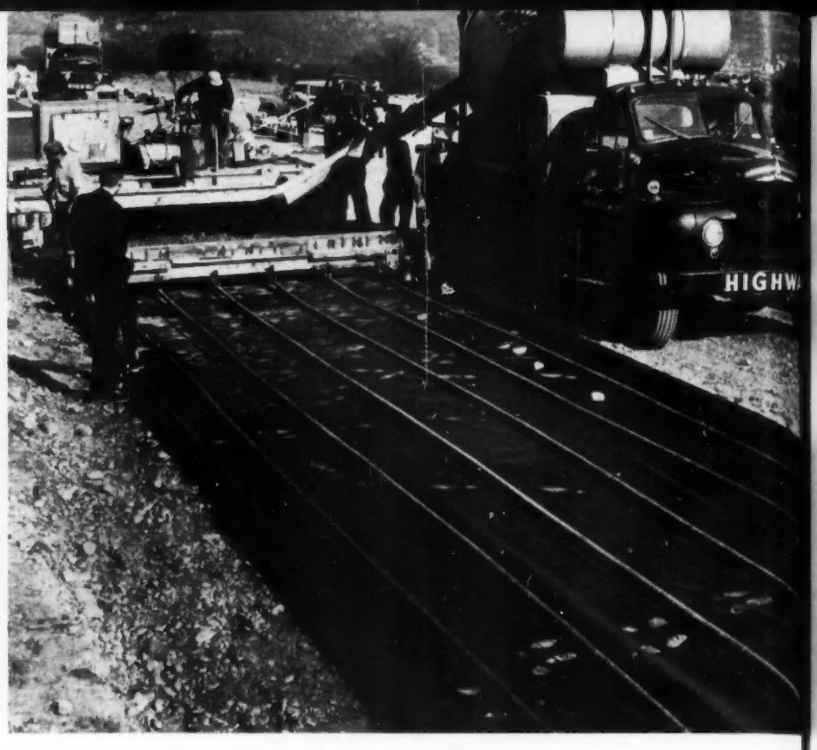


Because of the experimental nature of the prestressed concrete roadway built by Jones & Laughlin Steel Corporation in Pittsburgh, many improvisations were necessary in the construction. In this picture of the concrete placing, the wheeled device preceding the paver was made by Allegheny Contracting Industries, Inc., the firm doing the construction, to position the 'tendons"—the flexible conduits which contain the wire strands used for the prestressing.

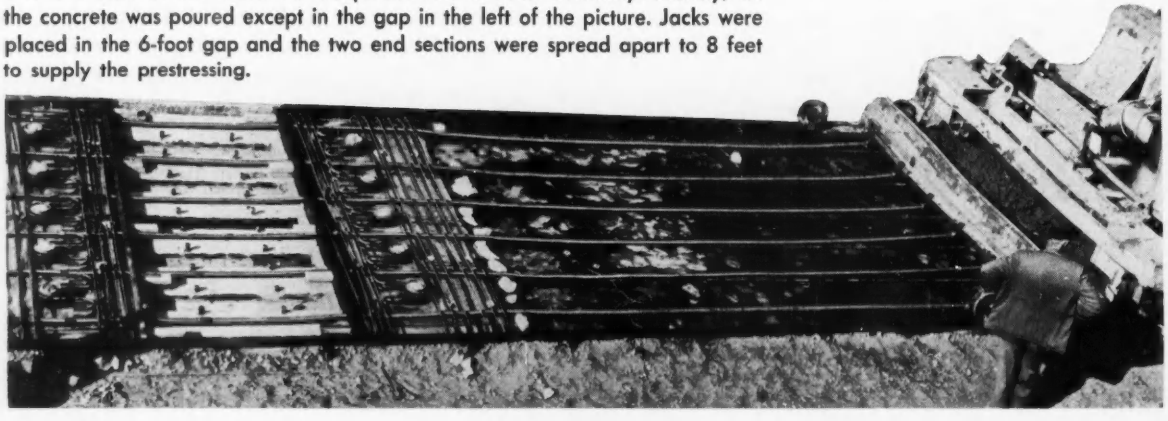
Experimental Highway of Prestressed Concrete

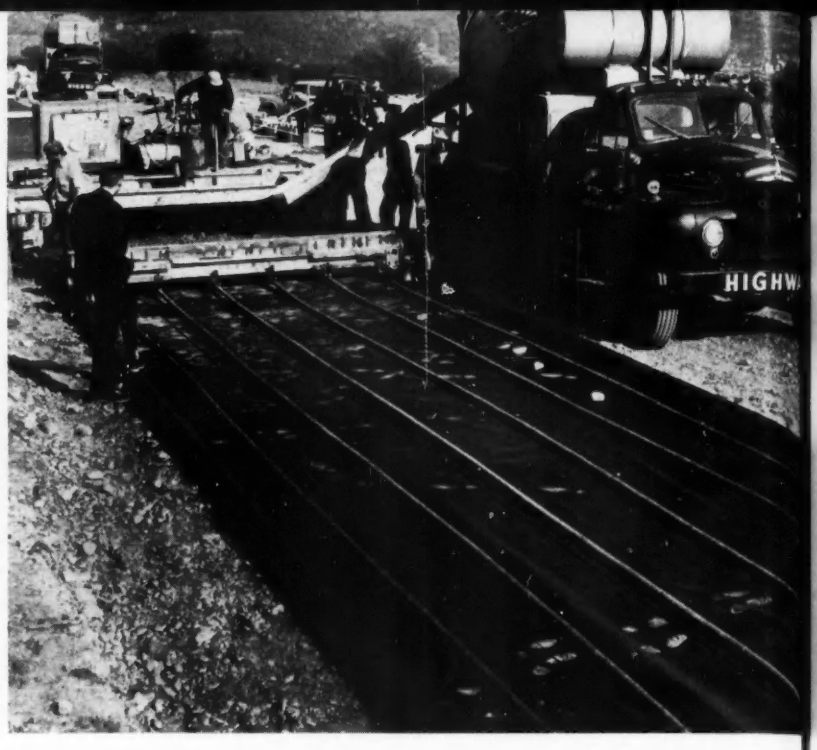
AN EXPERIMENTAL 600-foot stretch of pavement that may have a revolutionary effect on methods of highway construction has been built by Jones & Laughlin Steel Corporation. The project represents one of the first full-scale efforts on the part of private industry to determine the adaptability of prestressing techniques to highway construction problems.

The advantages of prestressed concrete have, of course, been known for some time. But the technique of prestressing concrete for highway use has presented some baffling problems that have remained relatively unexplored in this country. Many authorities believe that a prestressed concrete highway should have many advantages over a conventional road. The problem has been to find a practical and economical method of building it.

Essentially, the J&L experiment consisted of anchoring connecting wire strands at opposite ends of a 400-foot section of roadway. The strands pass through flexible steel conduits which were imbedded in the concrete. When the concrete for the prestressed section was poured, a 6-foot gap was left in the middle of the section. For the prestressing operation, large hydraulic jacks were placed longitudinally in the

This is a view of the center of the prestressed concrete roadway. Initially, all the concrete was poured except in the gap in the left of the picture. Jacks were placed in the 6-foot gap and the two end sections were spread apart to 8 feet to supply the prestressing.





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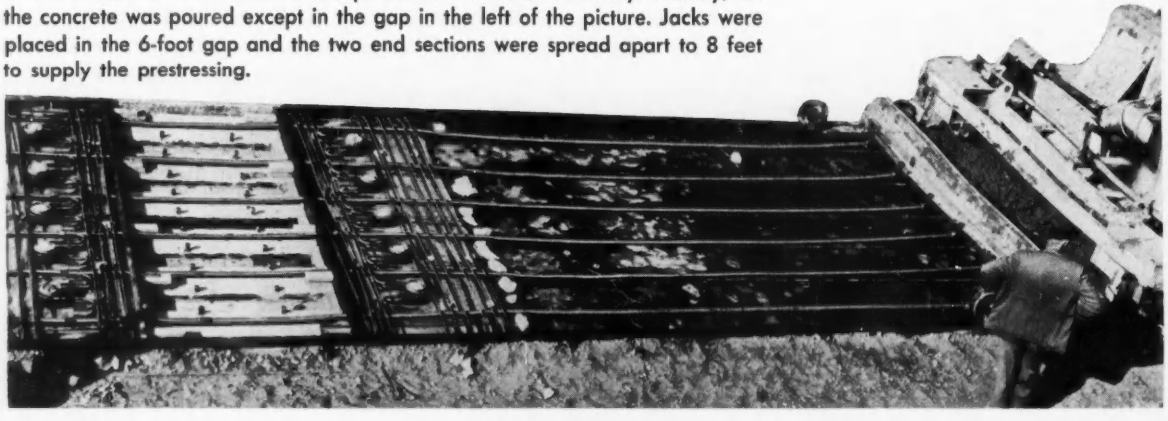
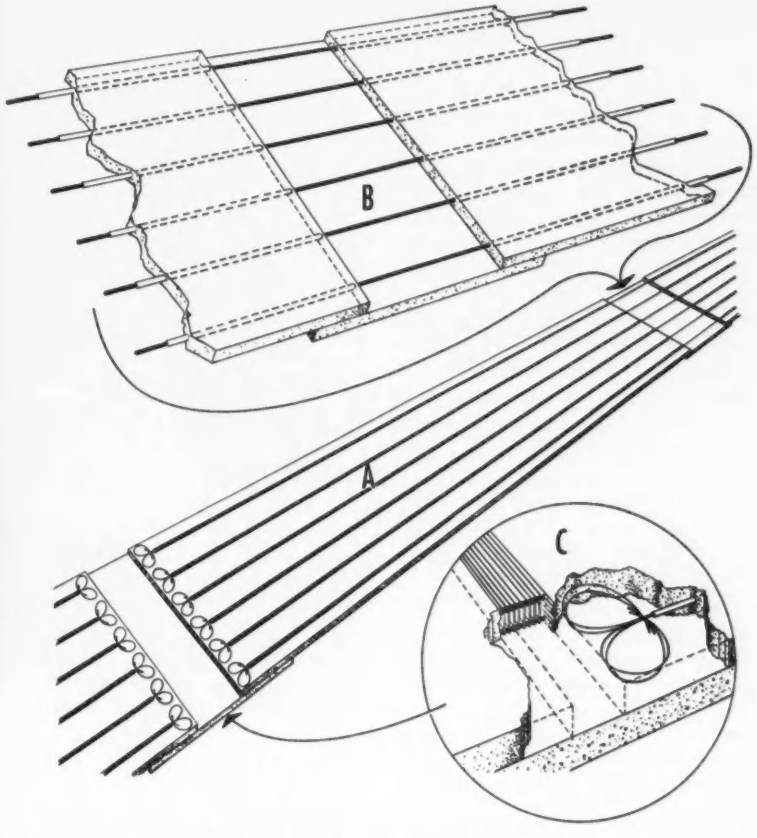




(A) An overall sketch of the experimental prestressed concrete roadway. Wire strands are anchored in the concrete at both ends of the slabs. These strands pass freely in flexible conduit through the entire length of the slab, including a six-foot gap in the center.

(B) An enlarged view of the gap in the slab. Jacks are placed in the gap. The jacking operation stretches the entire length of steel strands, prestressing and placing the concrete in compression. A device holds the slabs apart while the jacks are removed and the gap is filled with concrete.

(C) This shows the way in which the steel strands come out of the flexible conduit and are imbedded in the concrete. A special rubber joint has been developed to handle the expansion space between prestressed concrete slabs.

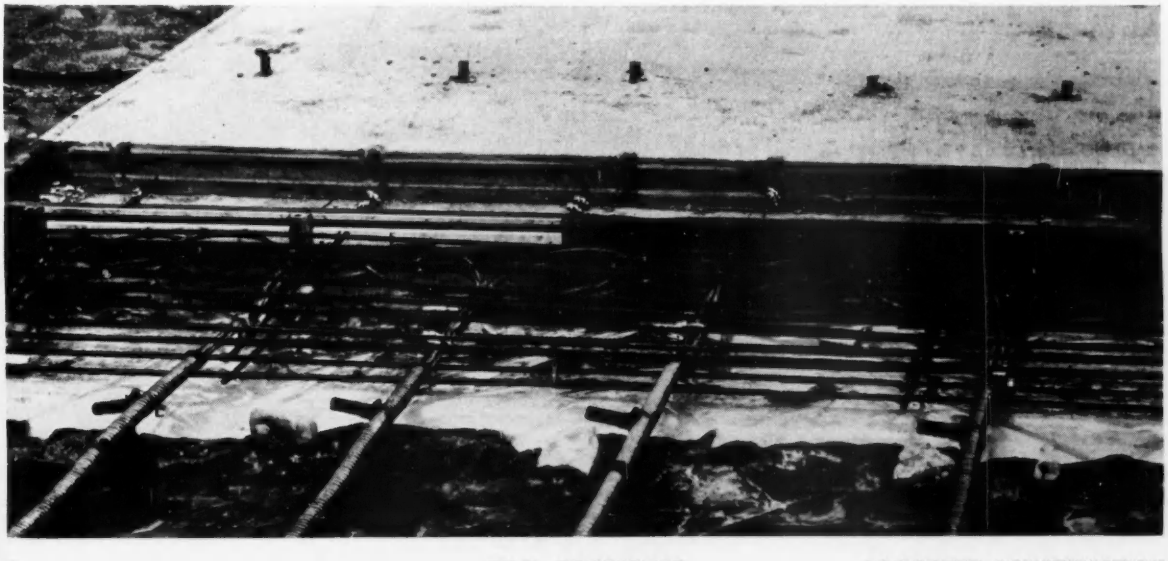
gap. When the concrete had set, the gap was jacked apart to a width of eight feet, far enough to produce the required tension in the wire strands, and consequent compression in the concrete. When this was accomplished, the jacks were removed (a special device was developed to hold the sections apart while this was done) and concrete poured into the gap.

Thus the entire 400-foot section of concrete was placed in compression as a result of the tension in the imbedded steel strands. The concrete slab is 5 inches thick, whereas most present-day highway pavements are 10 inches thick.

The experimental prestressed highway is designed to overcome one of concrete's inherent disadvantages. Concrete is weak in tension. In fact, its tensile strength—the ability to withstand being pulled apart—is only one-fifth to one-tenth of its compressive strength.

Present highway construction practice requires placing transverse joints at a maximum spacing of about 60 feet. These joints are necessary in concrete construction to allow for expansion and contraction. If the joints were

BELOW: This is one of the ends of the slab where the wire strands are anchored into the concrete. The strands pass out of the flexible conduit and are formed into a "butterfly" pattern to provide better anchorage in the concrete. The adjacent concrete slab is 100 feet long and also has been prestressed. A specially developed joint will be inserted between the two slabs for testing purposes.



not present, the concrete—being unable to withstand tension (pulling apart)—would crack.

However, the area around the joints is the place where most concrete eventually deteriorates because heavy loads, such as big trucks, press down on the edge of the concrete and create what is known as a "pumping" action.

The J&L prestressed section is 400 feet long. Thus seven joints are eliminated in every 400 feet—seven places where deterioration could take place. The concrete, although only 5 inches thick, is in compression. Therefore it is much stronger, right up to the joint.

The joint in the experimental road will have to be wider than the conventional joint because it will have to compensate for the expansion and contraction of 400 feet of concrete, rather than the customary 60 feet.

To find a suitable joint for such a width, the B. F. Goodrich Industrial Products Company has been conducting research, in collaboration with J&L. A prototype of a satisfactory joint has been made. A full-size joint soon will be installed and tested as part of the research on the experimental concrete section.

The joint, which is 12 inches wide and extends the full depth of the concrete slab, is designed to allow the top surface to remain level during maximum expansion and contraction of the concrete sections. The joint is believed to represent an entirely new concept. It includes a series of metal plates bonded to rubber to carry the vertical loads imposed by traffic.

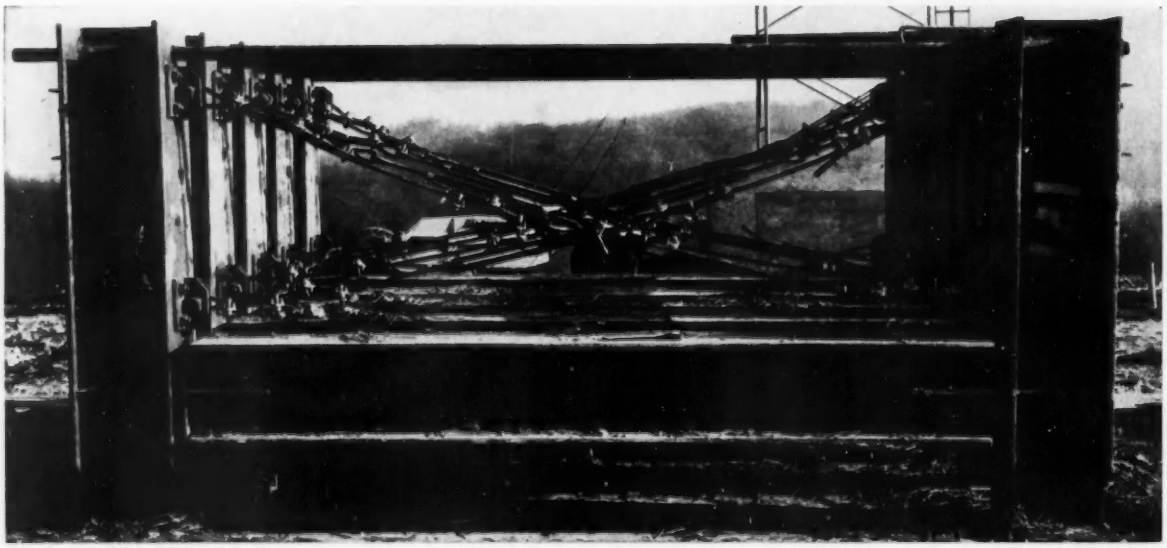
In addition to the main 400-foot section, a 100-foot prestressed section has been placed at either end, bringing the total length of the experimental road to 600 feet. Thus two joints will be made available for testing purposes.

The idea for the experimental roadway was suggested by Admiral Ben Moreell, Chairman of the Board of Jones & Laughlin, who has been interested throughout his career in the mechanics and applications of concrete as a construction material.

As an officer in the U. S. Navy Civil Engineers Corps, Admiral Moreell established himself as an authority on concrete and reinforced concrete. In 1929 he wrote "Standards of Design for Concrete," considered a definitive work on the subject. END

RIGHT: A frame to hold the two slabs apart while the hydraulic jacks are removed, is shown being assembled. The ends of the vertical members of the frame fit into holes in the prestressed concrete. After the jacks are removed and the frame in place, the gap is filled with concrete.

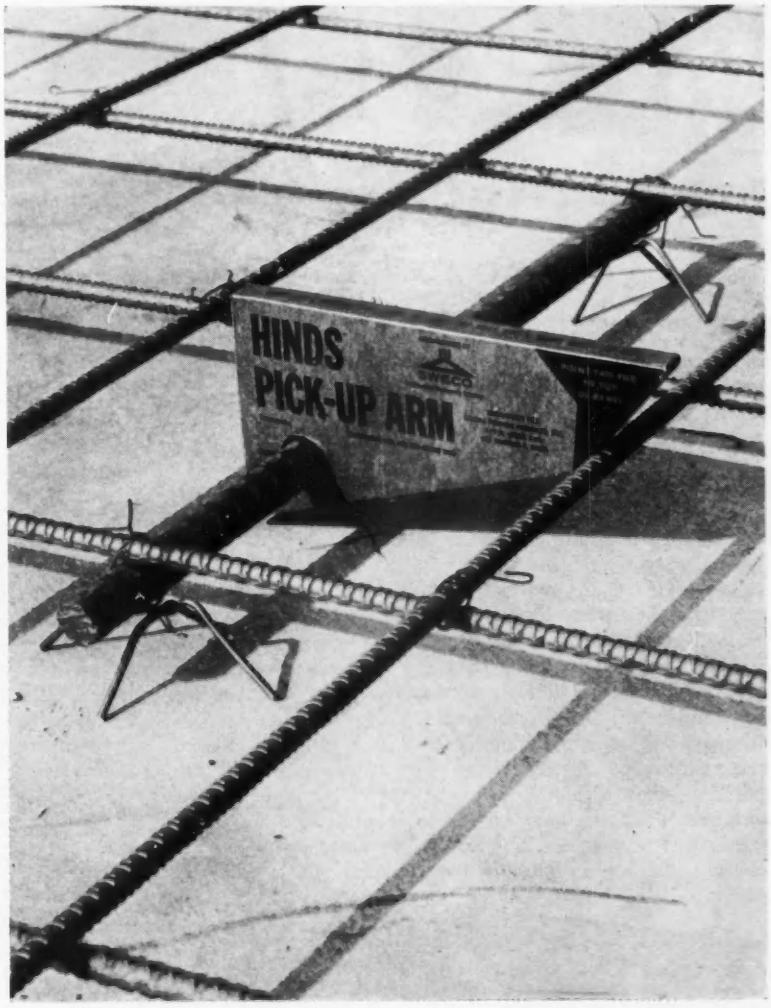
BELOW: This shows the assembled frame holding the two prestressed slabs in place while the concrete is placed and cured in the gap. After curing, the frame is dismantled and removed, making one continuous 400-foot prestressed concrete highway slab. The slab is now undergoing extensive tests.



PICK-UP ARM . . .

saves time in handling tilt-up slabs and also reduces danger of overstressing

The installation of the pick-up arm in its waxed carton is simply and quickly accomplished. The concrete is then placed around the carton which prevents it from setting against the hinge itself.



THE ADOPTION OF A NEW TYPE of device to raise tilt-up wall panels has resulted in savings of both time and money on the multi-million dollar project for the Lockheed Aircraft Corporation's Missile Systems Division plant in Palo Alto, California.

Known as the Hinds pick-up arm, it was used for lifting some 40 separate tilt-up panels on the 51,000-square-foot building, according to R. S. Knapp, general superintendent for the McNeil Construction Company, contractors on the job.

The pick-up arm, a simple steel bar with a hole in each end, was used in preference to the more usual procedure of bolting heavy angles onto inserts for picking up and setting the panels. A 2½-to 3-foot long piece of one-inch reinforcing rod is tied to the regular reinforcing net, adding strength around the pick-up point, and the pick-up arm is threaded onto it. The arm is delivered to the job in a waxed paper container with holes punched through both sides.

The bar, in its waxed carton, is rotated about the reinforcing rod when the lift is made. It acts precisely like a hinge. The outer part of the carton, with the bar inside, is level with the outside surface of the wall. The waxed carton acts like a form within the wall to prevent the poured concrete from setting against the hinge itself.

When the panel is ready to be lifted, the upper flap of the carton is torn away and the bar turned out of

the carton in an upright position. The crane shackle is attached at this point.

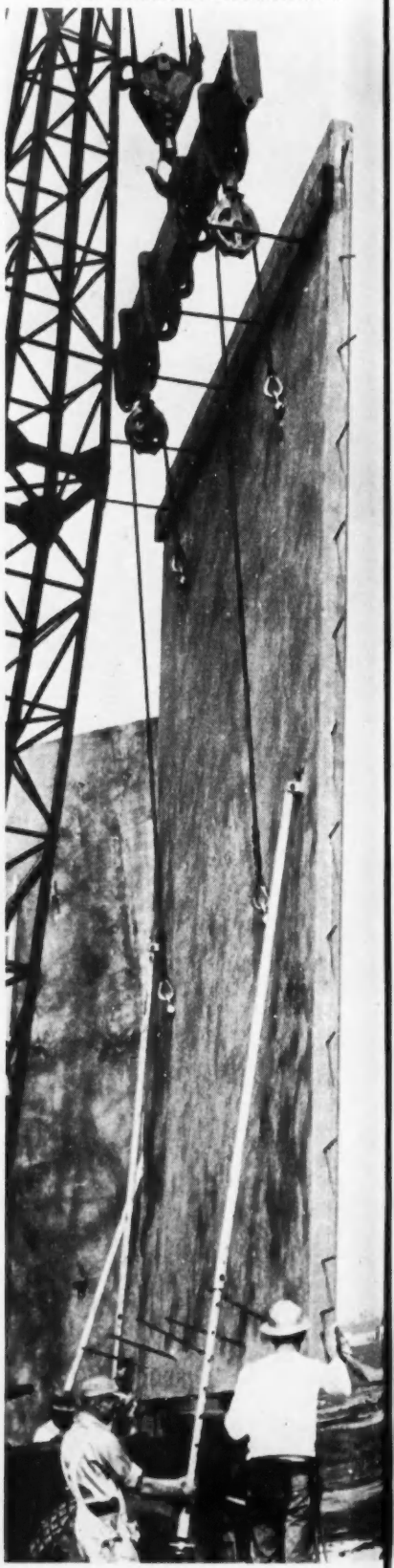
"It's a time and labor saver for several reasons," said Knapp. "For one, you don't have to bolt angles on the tilt-up panels. You just place the pin from the shackle through the hole in the arm. Time saved in placing and removing angles allows us to place more panels per hour and save rent on the cranes."

Experience on the McNeil job indicates that three men can attach four pick-up points in 30 seconds. Tilt-up panels on the building averaged 18 by 20 feet and were 6 inches thick. Other panels lifted on the job included a number of slabs 25 feet by 20 feet and 7½ inches thick, as well as some which measured 12 feet by 20 feet and were 12 inches thick.

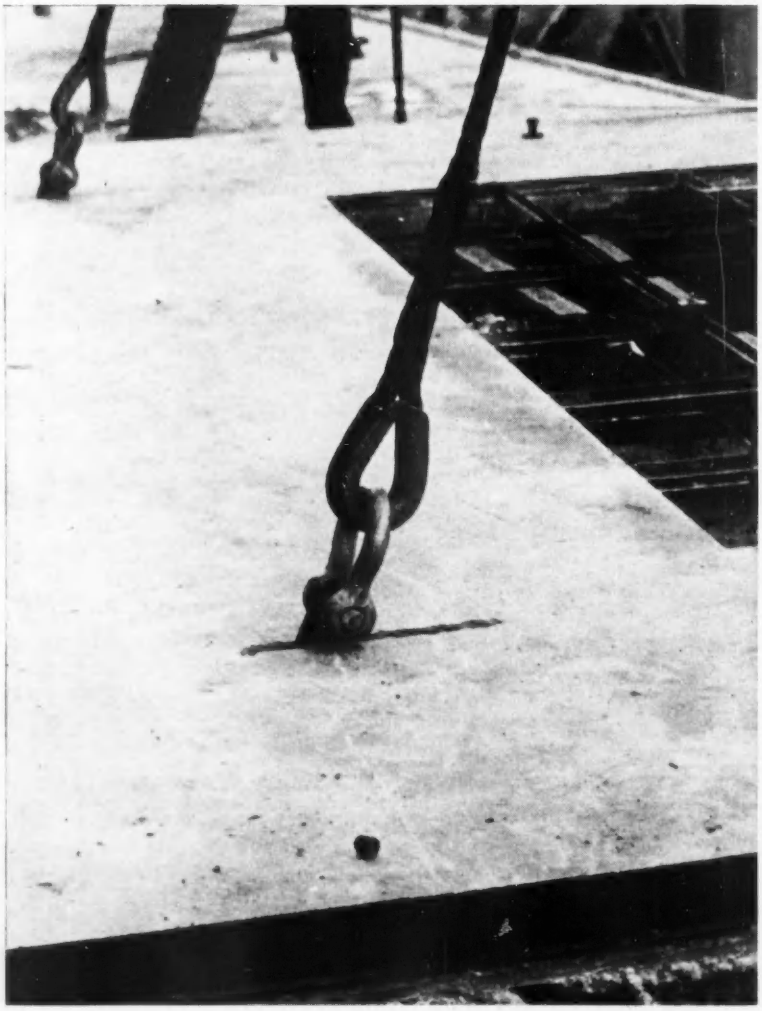
One of the most important features of the lifting device, according to the McNeil job superintendent, is that the bar prevents over-stressing the concrete as it is hoisted into a vertical position. With other devices developed for this purpose the lifting force is usually directed against the tilt-up sections at different angles as the slab is lifted. The resulting stresses often cause panels to crack and chip.

With the new device, the pick-up bar rotates on the reinforcing steel bar, avoiding stress against the pick-up point. After the wall is erected the bar is rotated back onto the groove and the opening grouted over. END

Photos courtesy Special Purpose Products, Inc.



When the panel is ready to be lifted, the exposed top of the carton is torn off and the bar rotated out of its slot. The crane shackle is then hooked up. During the lift the arm rotates on the reinforcing steel bar. This allows a straight pull in all positions and eliminates shear as the load is transferred to the curtain of steel.



In this photo, which also appears on the cover, note how the wire fabric has been overlapped and placed at a level above the ground to assure continuity and complete effectiveness of reinforcement.

No matter where you stand on the question of reinforcing slab-on-ground construction, you'll find food for thought in this down-to-earth discussion of why and how to use . . .

Welded Wire Fabric Reinforcement

SIX FACTORS are chiefly responsible for the quality of concrete ground slabs: sub-base, mix, placing, reinforcement, finishing, and curing. Of these, reinforcement is probably the least understood even by some knowledgeable contractors. Unfortunately it is often omitted altogether.

The omission of reinforcement, of course, is due to misunderstanding of its function and failure to recognize that performance, or lack of performance in terms of cracked and disintegrated concrete, is governed by all six factors cited, even in slabs on the ground.

That this is no ivory tower problem is underscored by sidewalks, driveways, foundation slabs, basement floors and other concrete projects around homes and shopping centers which have NOT performed properly, have cracked, or, putting it bluntly, have failed. Failures hurt everyone concerned—the architect, the contractor, the ready-mix producer, the owner, and, by extension, the entire concrete industry.

When proper attention is paid to sub-base, placing, mix, finishing, and curing, improved performance of ground-slab construction can be virtually assured by the sixth factor—proper reinforcement. Happily, the use of reinforcement is neither complicated nor time-consuming.

The basic reason why a steel reinforcing material such as welded wire fabric is needed in a concrete ground slab is the nature of concrete itself. This massive, durable, long-lasting material is strong, but *only* in compression. It can bear tremendous direct compressive loads, but has little resistance to tension. Translating from engineering gobbledegook, it can be squeezed (compressed) like a block in a vise, and it won't fail. But tighten (tension) it like a violin string, and it'll break.

And it's tension, or the tensile, pulling forces in a concrete ground slab, that cause most of the failures. These tensile, destructive forces, moreover, are not caused just by loads on the slab, such as an automobile on a driveway. When concrete is first poured, for example, it's subjected to tremendous tensile forces as the plastic mix sets up, shrinks and attempts to draw in upon itself. Actually, concrete is at its weakest during its first six hours of life, and at this time may easily crack itself!

Other tensile forces affect the concrete slab throughout its life. Concrete expands and contracts with temperature changes of the air and ground, and with changes in the moisture content of air and ground. The expansion it can take, but the contraction exerts a pulling or tensile force and may crack the concrete. Slight shifts or settlement of the sub-base causes bending or twisting of the slab, and this, too, sets up crack-producing, tensile forces.

Now what does a distributed steel reinforcement do about all this? By

adding fabric to the slab, you add tensile strength, since steel is extremely strong in tension. Therefore, when the slab shrinks or contracts, when it is subject to the pulling, crack-producing forces caused by twisting or warping, the steel resists these tensile stresses, distributes them evenly over a large area, and tends to hold tightly together and minimize any cracks which form.

The use of the word "minimize" should be carefully noted. The function of the steel fabric is not totally to *prevent* cracks in concrete (an impossibility), but to keep the cracks tightly closed or "minimized." With the fabric holding the edges of the crack tightly together, for all practical purposes there *is* no crack.

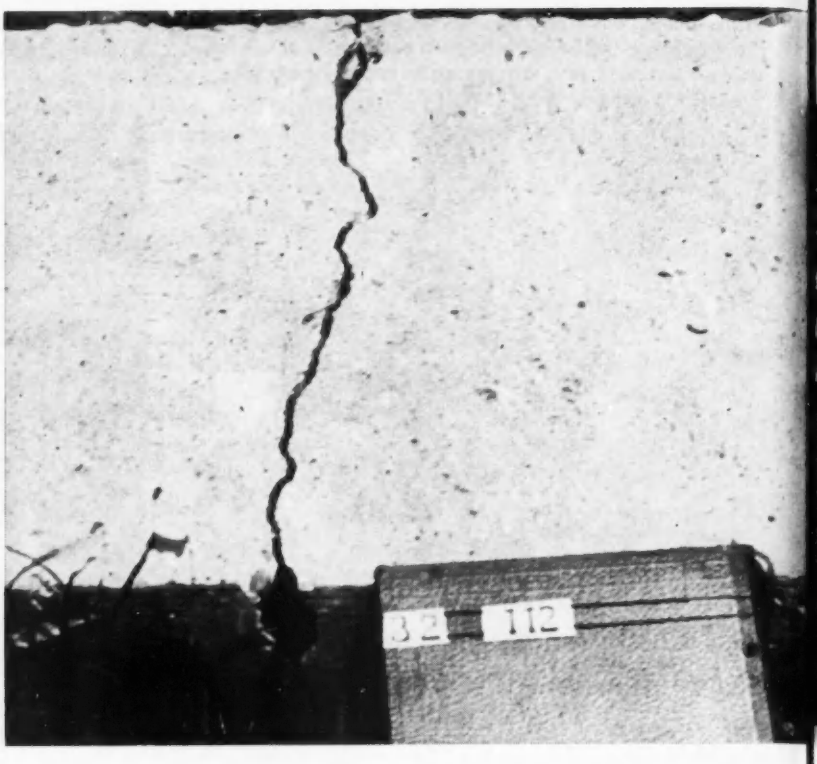
In the unreinforced slab, however, when cracks form, there's no resistance to their opening up, becoming unsightly, dangerous, and a source of further deterioration, as they are penetrated by dirt, water and even insects.

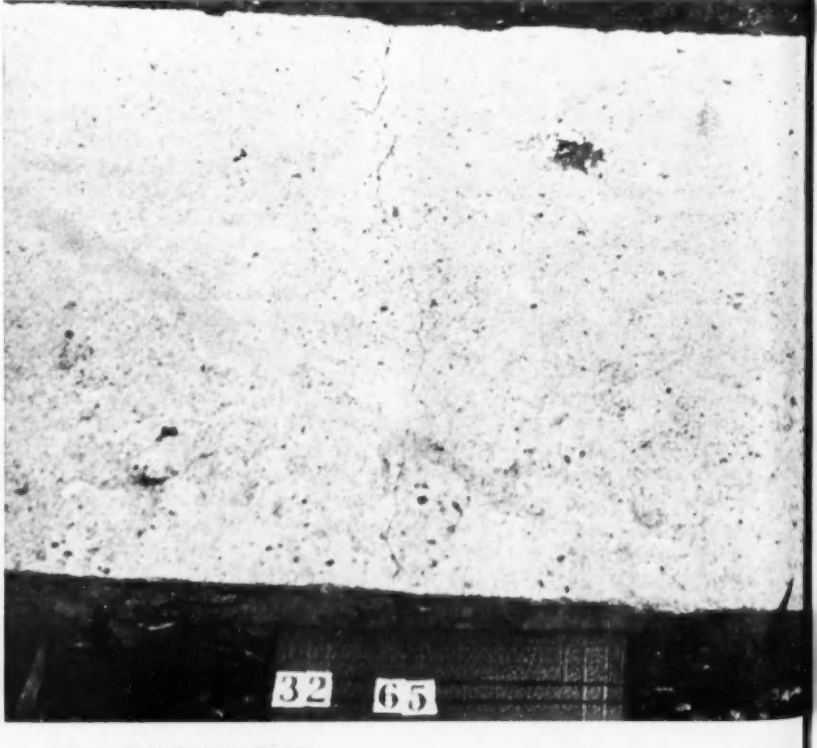
From the standpoint of the builder or contractor, the reinforcement with welded wire fabric of all concrete flat work might be regarded as a very modest insurance fee that his work will long be a mark of credit to himself and the entire building industry. Although reinforcing is only one of the six factors influencing quality, and is NOT a cure-all for poor construction practices, it will tend to minimize any crack damage which does result from inferior sub-soil or improper curing, for example.

The cost of this insurance is low. Welded wire fabric for any given slab about a home or store represents usually about 6 or 7 per cent of the cost of the materials for the total concrete job.

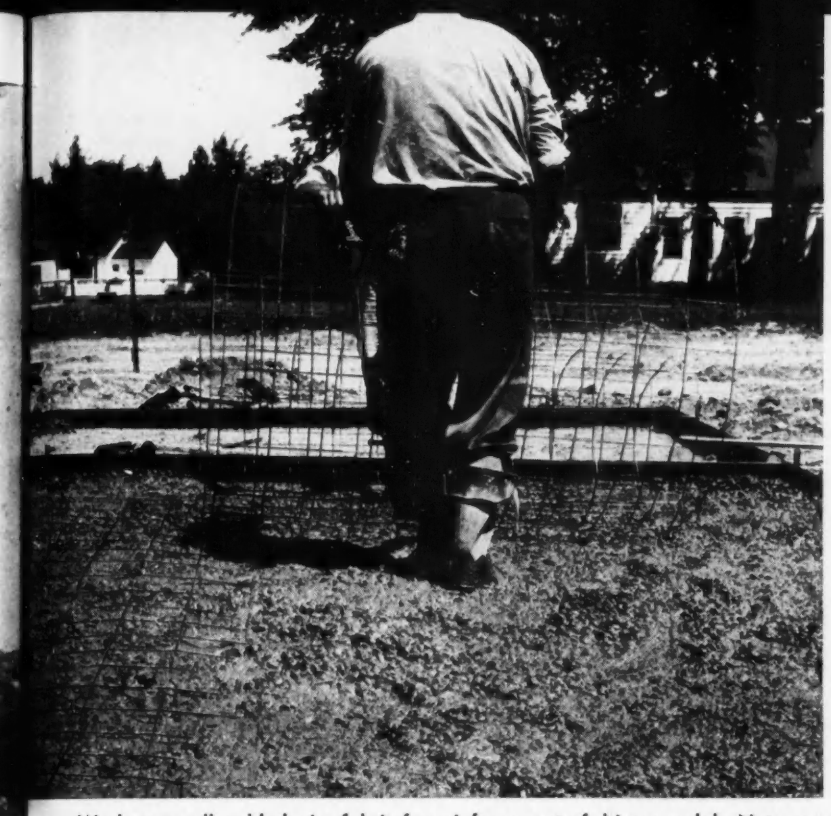
Emphatically substantiating the "insurance" function is the fact that actual deflection tests show that wire reinforcement adds as much as 30 per cent to the strength of the slab. The contractor can provide a tremendous margin of safety for literally pennies a square foot.

Aside from a misunderstanding of the functions of fabric in preserving the life of concrete, the use of the material has sometimes proved a stumbling block to contractors. The observance of a few simple precautions and hints based on the know-how gathered over the years by men on the job will save time and assure effective reinforcement for every job. (More)





Tests made by the United States experimental laboratory at Arlington, Virginia, have demonstrated that welded wire fabric keeps cracks in concrete closed. The concrete slabs pictured are the same thickness, composition, and age, and have been exposed to the same climatic and ground conditions. The slab above contains no reinforcement and the crack has noticeably opened. Below, the slab has been reinforced with wire fabric, and the crack is almost invisible.



Workers unroll welded wire fabric for reinforcement of driveway slab. Note overlap, on left, of one wire space. This assures positive continuity of reinforcement. Ready mix has been struck-off at mid thickness.

GENERAL INFORMATION

Cutting and Forming: Welded wire fabric is easily cut with ordinary wire cutters. Where it is necessary to interrupt the reinforcing for part of a structure (a drain in a floor, for example), simply cut out around the protruding part and lift away a section of the fabric, or notch out a section at the edge of a slab to fit around a corner post of a porch for example.

To form welded wire fabric, as for steps on the ground, use a 2 by 4 or 4 by 4 as a template, and bend over it by hand.

Placing the Fabric: Fabric reinforcement may be positioned in plastic concrete in one of three ways. The first method is to place the concrete about one-half the desired slab thickness, strike off, then place the reinforcement and a second course of concrete without delay so that the courses bond together completely.

A second method eliminates the need for two pours. Piles of ready-mix which lack about one-half the desired slab height are placed every three to five feet about the prepared sub-grade, the fabric placed across these piles, and the entire slab thickness poured. The piles will keep the reinforcement in the correct position, in the center of the slab. If, in pouring, the fabric tends to droop too low between the piles, a rake or hook is used to lift it back into place.

A variation on the foregoing, which may save even more time, is to have brickbats of the proper height placed about the sub-grade (instead of the piles of concrete) before the ready-mix truck arrives.

Many concrete contractors place the reinforcement directly on the sub-grade, and use rakes or hooks to lift it into proper position as the concrete is being poured. This method requires good judgment and extreme care to assure that the welded wire fabric is not left on the sub-grade where it is valueless in controlling and minimizing cracks.

Lapping and Clearance: By overlapping the welded wire fabric at least one space at the ends and sides of the rolls, the effect of continuous, unbroken reinforcement is gained with no gaps where cracks might form. (Space refers to wire spacing; that is, 6X6-10/10 fabric would be overlapped about 6 inches at the ends and sides of rolls. Nest the overlaps for a snug fit.) Sometimes laps are wired together to assure continuity.

As a general rule, allow 1½ to 3 inches of clearance between the fabric and the formwork. For example, to reinforce a sidewalk 5 feet 3 inches to 5 feet 5 inches wide, a 5-foot wide roll of fabric would allow 1½ to 3 inches of clearance.

Vibrating: Thorough vibration or rodding of the plastic concrete is recommended in order to be sure that the mix is distributed completely and that the fabric is properly embedded all around, so that it can best perform its function of adding tensile strength to the finished slab and thus control and minimize cracking.

Ordering Fabric: Size or style of fabric is designated by two pairs of figures which refer respectively to the spacing of the wire members and their gauges. For example, 4X4-6/6 (spoken "four-four-six-six") refers to steel welded wire fabric having number 6 gauge longitudinal and transverse wires, spaced at 4 inches in each direction. (The first of each pair of figures refers to the longitudinal wire.)

When ordering fabric requirements from a building supply dealer or distributor, allow about 10 per cent extra for lapping of sheets or rolls.

SPECIFIC CONSTRUCTION HINTS

Here are a few Do's and Don'ts that will save time and assure proper performance of wire fabric.

Basement Floors: If the floor area is divided by a joint, the fabric must not pass through the joint, but should stop 1 to 3 inches short of it. One to 3 inches of clearance must be allowed between the fabric and basement walls. Additionally, allowance should be made for an expansion joint of mastic or oakum between floor and wall.

Driveways: A 5- or 6-inch slab is generally satisfactory for a residential driveway. The reinforcement must not pass from slab to slab, but should stop one to three inches short of the joint between slabs. Be sure to lap the lengths of fabric used to reinforce the drive. For example, a 12-foot wide drive could be reinforced with 11½-foot lengths of wire cut from a 5-foot roll of 6X6-6/6, the 5-foot

roll being the standard size stocked by most building supply dealers. The lengths should be placed transversely between the side forms for the drive, and overlapped about 6 inches.

Garage Floors: Here, as for driveways, a 5- or 6-inch thick slab is recommended, along with the heavier residential style fabric, 6X6-6/6, to sustain the weight of vehicles. Fabric must not pass through the joints between slabs (in the case of a double garage).

Patios & Terraces: A 4-inch thick slab is usually satisfactory for these outdoor living areas. If a barbecue pit or outdoor fireplace is included in the plans, be sure to figure on at least a 6-inch thick slab, reinforced with 6X6-6/6 or 4X4-6/6 fabric to withstand the weight of the fireplace.

Porches: If a porch is to be 2 feet or less above ground level, it is economical to build it like a patio or terrace over an earth and gravel fill. Higher porches, however, supported on piers of concrete or brick, require formwork to pour (for example) a 6-inch slab.

Because concrete has little ability to resist pulling apart or tensile forces, a concrete porch slab suspended between piers requires reinforcement near the bottom to give it strength as the slab bends under loads, including its own weight. Use fabric 6X6-6/6 for spans up to 6 feet, and 6X6-4/4 for spans from 6 to 8 feet. Fix the fabric in position with nails or wooden blocks 1 inch above the bottom form.

Sidewalks: To save handling time, order fabric for sidewalks in walk-width size, or multiples. For example, a 5½-foot wide walk could be reinforced with a length of fabric from a 5-foot wide roll, placed longitudinally, thus allowing 3 inches of clearance on each side. If dummy joints are formed for appearance sake, do not break the fabric under these joints, but let it run continuously from true joint to joint. If vehicles are to cross a portion of the walk, the concrete in this area should be 5 to 6 inches thick, and the amount of reinforcement doubled by placing two layers of fabric, nested in each other. When figuring amount of fabric for narrow sidewalks, it is unnecessary to allow extra for longitudinal lapping. (More)

After placing wire reinforcing, style 6x6-10/10, the worker cuts the fabric to fit the form, allowing about 2 inches clearance from the form sides.

The picture below shows the reinforcement placed directly on the sub-grade, and as the concrete is placed, a hook (see arrow) is used to lift fabric into proper position. If left resting on the sub-grade the wire fabric wil be of little help in preventing cracks.

Residential Foundation Slabs: A thickness of 5 inches is recommended for slabs over good soil. One of fabric's inherent advantages in slab type construction is that electrical conduit work, plumbing and other work may be done even after the steel wire is in place.

Steps: The function of reinforcement in steps (not on the ground) is similar to that in porches. The steel resists the pulling-apart forces caused by the weight of the steps as they deflect or bend down. Fabric style 6X6-6/6, positioned 1 inch from the bottom form, held in place with nails or inch high wooden spacers, is recommended for up to 5 risers. If more than 5 risers are to be built, use a heavier gauge fabric. For steps on the ground, such as up to a terrace, use 6X6-6/6, formed to fit the risers, and positioned about 2 inches from the surface. END

Concrete Projects Recommended for Welded Wire Fabric Reinforcement

Driveways

Foundation Slabs
(Residential only)

Basement Floors

Garage Floors

Sidewalks

Steps

Porch Floor

Patios & Terraces

Barbecue

Foundation Slab

At the left, excessive cracking has destroyed most of the driveway's usefulness. In contrast, the driveway pictured below has been reinforced, serves two families, and after five years of carrying many heavy vans and delivery trucks—no cracks show.

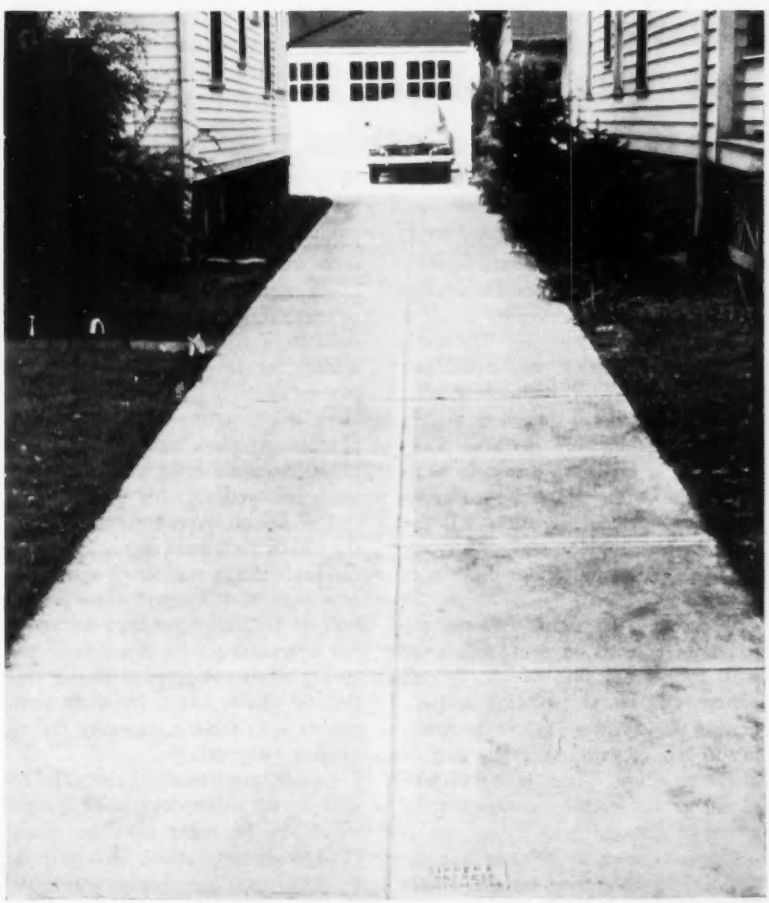


Photo courtesy National Rubber Bureau

Stripping off the figured rubber matting to reveal just one of a wide variety of surface patterns that can now be obtained simply by lining formwork.

More Notes on Patterned Concrete Surfaces

SOME MONTHS AGO (September, 1956, issue, page 10) we told briefly about a technique of casting concrete against ordinary rubber sheeting to create a variety of figured surfaces. The work on which our article was based had consisted mainly of precast concrete.

Since our original story was written some interesting work has been done, especially in England, to achieve similar results with job-placed concrete. The basic procedures are much the same for cast-in-place work as for precast, although some minor differences are apparent.

Reduced to its simplest terms, the technique consists of lining formwork with rubber sheeting of the desired pattern and texture, placing and vibrating the concrete against the sheeting to cast its pattern into the surface of the structure. The sheeting may be glued to the forms or fastened by means of clips.

Opinions seem to differ on the desirability of using form oil to facilitate stripping. Where it is used at all, there seems to be some preference for castor oil because of the adverse effect of mineral oils on rubber. Some work has also been done in the use of lime washes for this purpose. When no parting agent is used, it is desirable to allow ample setting time before stripping so that green concrete will not be pulled from the mass when the sheeting is removed.

The British experimenters say that the use of such linings creates no special problems in concreting operations. Moreover, they agree that the production of a finished textured surface in one operation results in a definite cost saving when compared with the creation of similar effects by other methods, such as tooling, exposing the aggregate, or gunning.

Equally good results seem to be obtained with either external or internal vibration. In either case the quality of the finished surface is largely dependent upon the thoroughness with which the concrete has been vibrated. Being both tough and resilient, the rubber sheeting readily withstands any normal abrasion resulting from direct contact with a vibrator spud. Since normal mixes are preferred for this type of work, one important purpose of thorough vibrating is to bring fine materials to the surface in order to cover all the aggregate completely.

Although much of the work on textured form linings has been done overseas, there has been growing interest in the technique here in the United States. Figured Plywood and plastic-coated papers have been used with good effect here, and a few designers are beginning to experiment with textured sheet rubber. Whatever the outcome of these experiments, it seems virtually certain that the creation of aesthetically acceptable concrete surfaces will no longer be dependent upon the costly and arduous hand methods that have dominated this field in the past. END

Here are some hot tips on . . .

Summer Concreting

MAN WAS MADE TO TOIL under the hot sun, and the concrete contractor in particular must toil with materials that often react unfavorably to heat.

You'll face special problems in the handling, working, and curing of concrete in the hot days ahead—and all of them have to do with moisture, either too much of it or not enough. When temperatures soar and the concrete mix delivered to you stiffens faster than it ordinarily does, it's a natural temptation to want to add extra water to the mix. However, adding extra water reduces the strength of the concrete. This was demonstrated by tests made at the University of Maryland, which showed that three gallons of extra water per cubic yard of concrete resulted in a 300 psi reduction in the 28-day compressive strength.

Your ready mix supplier knows just how much water to use for summer concreting purposes. Trust his knowledge and use the material he delivers in the form in which it is delivered to you to get the best results.

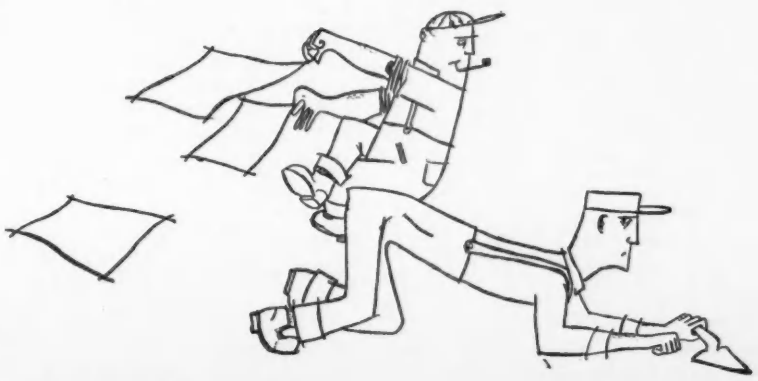
The biggest problem you'll face under the sun will be the rapid evaporation of water. This can lead to surface cracking as the concrete dries and shrinks too fast to accommodate itself to the volume change. It usually happens just when the concrete is ready for final finishing.

Since the big problem in summer concreting is, therefore, moisture control, here are some tips you can follow to be prepared in advance or to take quick on-the-job action.

Undertake any summer concreting job on a tight schedule so that the placing and curing operations are carried out in the shortest possible period of time.

For any summer concreting job be well prepared with certain materials: Bring canvas and lumber for sunshades and windbreaks to protect the fresh concrete. Bring tanks full of water along—not for pouring into the ready mix, but to keep subgrades, forms, and the freshly placed concrete continuously moist. Under certain conditions, water can evaporate in these tanks as well as in the concrete surface, so make sure that whatever containers you use are protected from the heat, either through insulation or by painting the outside in a light color that will not absorb the sun's rays.

Before pouring the concrete, thoroughly moisten all forms and the entire surface of the subgrade. This is to keep these materials from absorbing the moisture in the concrete.

Start curing the concrete as soon as you can work the surface without marring it. Right after floating, put canvas covers up over the entire surface. If there's a hot summer wind blowing, put up windbreaks as well. With all this precaution, you will still find it necessary to sprinkle the surface of the fresh concrete throughout the curing stage. The surface must be continuously wet, even if you have to detail one man to handle this job. It will be well worth it to prevent the possibility of plastic cracking. The application of curing compounds to the surface is also very helpful, but nothing substitutes for a continuous spray of moisture.

Moisture, then, is your chief weapon in the fight against the sun's hot rays—moisture properly applied to forms, subgrade, and during the curing stage of freshly placed concrete. END